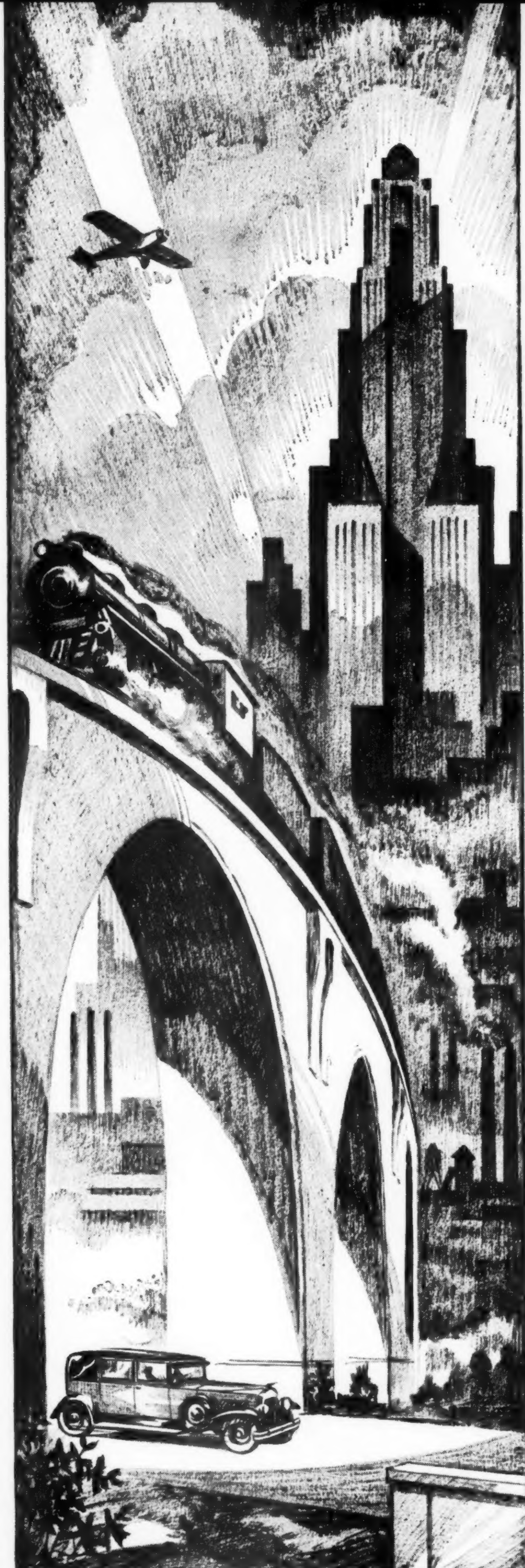

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J. R. BOYD, Editor

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THE CRUSHED STONE JOURNAL

WASHINGTON, D. C.

Vol. XIV No. 4 JULY-AUGUST, 1939

Selection of Aggregates for Concrete Pavement Based on Service Records[1]

By CURTIS CANTRILL[2] and LOUIS CAMPBELL[2]

SYNOPSIS

This paper presents the service record of various aggregates as indicated by a concrete pavement condition survey. The purpose of the investigation was to determine (1) aggregates having unsatisfactory service records, and (2) standard tests which would eliminate future use of these aggregates.

The condition survey consisted of a classification of all types of cracking and surface disintegration, which was then correlated with construction data and laboratory tests. Analyses of the data established aggregates having unsatisfactory service records.

Examination of the concrete in which certain aggregates were incorporated showed that a large decrease in flexural strength had occurred. This condition was especially noticeable in chert gravel pavement after a period of exposure varying from 2 to 5 yr. Flexural tests on laboratory specimens manufactured from chert gravel and subjected to 40 cycles of freezing and thawing in the presence of water substantiated this observation. A decrease in flexural strength as high as 100 per cent was observed for specimens containing chert gravel obtained from the Tennessee River, 15 miles above the mouth. Chert gravel from the Cumberland River at Clarksville, Tenn., showed results slightly better. This material has successfully passed all standard tests for soundness and wear. Field specimens of chert gravel concrete have always passed the usual strength requirements.

This investigation indicates that failure and disintegration of concrete pavement throughout the western part of the state resulted from the use of chert gravel obtained from the Tennessee and Cumberland Rivers and that the fine aggregate did not contribute to this failure. Chert gravel may be eliminated by standard tests outlined in this paper.

Crushed sandstone resulted in satisfactory pavement when used with Ohio River sand, whereas when used with sand manufactured from sandstone it resulted in unsatisfactory pavement.

PREVIOUS to July 1, 1937, the Kentucky Department of Highways constructed 183 projects, or approximately 1100 miles of concrete pavement. A number of the projects have given excellent service while others have failed, necessitating expensive replacements. Failures due to subsoil conditions, drainage, etc., have occurred but have been eliminated from the comparisons of the service record of aggregates. The predominant failures take the form of progressive scale followed by disintegration of the concrete. This investigation was undertaken in an effort to eliminate, or reduce to a minimum, future concrete pavement failures.

Crushed materials used in pavement construction were limestone which is prevalent throughout the state, and eastern Kentucky sandstone. Uncrushed Ohio, Tennessee, and Cumberland River materials were used. The Ohio River material was obtained between Huntington, W. Va., and Paducah, Ky. Tennessee and Cumberland River materials were obtained in the western Kentucky area only.

An extensive condition survey of the existing pavement was started during 1937 and completed in 1938. A separate data sheet, divided into sections, was compiled for each paving project. The first section contained construction data and laboratory tests, and the second a tabulation of the condition survey. The condition survey consisted of a classification of all types of cracking and surface disintegration. Projects

[1] Presented at the Forty-Second Annual Meeting of the American Society for Testing Materials, June 26-30, 1939.

[2] Senior Materials Engineer, and Materials Engineer, respectively, Kentucky Department of Highways, Frankfort, Ky.

were divided into one-mile sections for convenience in surveying. Distances were measured with a Stewart-Warner Odometer calibrated in feet. Analyses of the completed data sheets constitute the basis of this paper.

In addition to the field survey, a series of laboratory tests were made on aggregates from representative sources, and on concrete beams in which these aggregates were incorporated.

FIG. 1.—DISINTEGRATED PAVEMENT.
Map cracking well developed. Tennessee River gravel—O.R.B.T. sand. Age, 5 yr.

SURVEY SUMMARY

Located in the western part of the state are 59 miles of concrete pavement which were classed as a major failure from the survey. The age of this pavement varies from 2 to 7 yr. Coarse aggregate used in all of the separate projects was obtained from the Tennessee and Cumberland Rivers in the western Kentucky area. Fine aggregate was obtained from the Cumberland River in western Kentucky and two distantly separated sources in the Ohio River. The first source of Ohio River material was approximately one mile below the mouth of the Tennessee River, the material hereinafter being referred to as O. R. B. T. sand. The second source was near Henderson, Ky., or approximately 100 miles upstream from the first.

The aggregate combinations that had been used in the unsatisfactory pavement were as follows:

Tennessee River gravel, O. R. B. T. sand (Fig. 1),
Tennessee River gravel, Ohio River sand, and
Cumberland River gravel, Cumberland River sand.

In the same area are 145 miles of concrete pavement varying in age from 4 to 7½ yr. which was classed as satisfactory. Aggregates used in this pavement were crushed limestone, Ohio River gravel, O. R. B. T. sand, and Ohio River sand.

Aggregate combinations that had been used in the satisfactory and durable pavement were as follows:

Crushed Limestone, O. R. B. T. sand (Fig. 2),
Crushed Limestone, Ohio River sand, and
Ohio River gravel, Ohio River sand (Fig. 3).

One project was constructed using only Ohio River sand in combination with gravel from the Tennessee and Ohio Rivers. The section in which Tennessee River gravel was incorporated failed, while the section in which Ohio River gravel was used has a satisfactory service record (Fig. 4). Another project contained crushed limestone, Tennessee River gravel, and Ohio River gravel with the same sand and cement throughout. Failure resulted for the Tennessee River gravel section only.

By comparing pavements of different ages we find the following facts concerning disintegration. Transverse cracks form in the newly laid pavement, and after a certain period small map cracks form, radiating in all directions from the transverse crack which is the initial step in disintegration. After another period, progressive scaling sets in which is closely followed by general structural failure of the concrete. The condition outlined requires different periods with different aggregates; 1 to 2 yr. to show signs of disintegration, and 3 to 5 yr. to break down completely has been observed for chert gravel pavements. Ohio River gravel pavements were found to require 4 to 6 yr. to show map cracks, with only a very small amount of progressive scale developing at any age. Pavements constructed of crushed limestone show practically no sign of disintegration at

FIG. 2.—BATES TYPE PAVEMENT.
Note markers at transverse cracks. This Project on the basis of the survey is the best that has been constructed by the Department of Highways. Length, 10.12 miles. Average transverse crack count, 49 per mile. Age, 6 yr. Crushed limestone, O.R.B.T. sand.

any age. The only trouble found in limestone pavement is directly traceable to a high percentage of shale. The comparative durability and cracking of pavement constructed of various aggregates may be seen from Table I.

From the project survey sheets and the above, it is evident that Tennessee and Cumberland River gravel appeared as coarse aggregate in all major pavement failures occurring in western Kentucky, and that the fine aggregates did not contribute to this failure. Fine aggregate obtained from the Ohio River either above or below the mouth of the Tennessee River is a well-graded quartz material and has been used successfully with limestone or Ohio River gravel.

Crushed Sandstone Fine and Coarse Aggregate Results in Unsatisfactory Pavement:

An experiment was conducted to determine the desirability of eastern Kentucky sandstone as an aggregate for concrete pavement. The native sandstone used was composed of a silica sand with an iron oxide cement. Deval abrasion tests on this material gave an average value of 6 per cent, and toughness tests an average value of 8.

Projects were constructed using crushed sandstone for both fine and coarse aggregate. A total of 18.29 miles of pavement was constructed, 0.37 miles of which were classed as broken and replaced area. Natural transverse cracks averaged 107 per mile, 13 per cent of which was raveled or spalled, 84 per cent

FIG. 3.—BATES TYPE PAVEMENT IN EXCELLENT CONDITION.
Ohio River gravel, Ohio River sand. Age, 5½ yr.

scaled, and 1 per cent showing initial disintegration. Progressive scaled area averaged 100 sq. yd. per mile. Blowups averaged 0.4 per mile. This pavement has a satisfactory natural transverse crack interval. However, the large amount of disintegration and failure occurring in 10-yr. pavement are factors that condemn the use of sandstone when used for both fine and coarse aggregate.

Crushed Sandstone Coarse Aggregate and Ohio River Sand Fine Aggregate Results in Satisfactory Pavement:

The total mileage constructed using crushed sandstone as coarse aggregate and Ohio River sand as fine aggregate was 7.94; 0.08 miles of which were

FIG. 4.—CONSTRUCTION JOINT, TENNESSEE RIVER GRAVEL ON LEFT AND OHIO RIVER GRAVEL ON RIGHT.
Ohio River sand used in both concretes. Age, 8 yr.

classed as broken, settled, and replaced area. An average of 81 natural transverse cracks per mile occurred in this pavement, 35 per cent of which was raveled or spalled, and 24 per cent scaled. No progressive scaled area or blowups occurred. The small amount of disintegration and failure occurring in 11-yr. pavement in which crushed sandstone and Ohio River sand were incorporated, recommends this combination for future construction.

LABORATORY TESTS

Changing comparison from the service record of pavements to laboratory abrasive, soundness, and strength tests we find chert gravel to be equal to limestone or Ohio River gravel.

Gravel from the Tennessee and Cumberland Rivers has passed all standard laboratory tests for abrasion and soundness. The average of tests made on various materials during the past 10 yr. are shown in Table II.

Strength tests on chert gravel concrete field specimens, with a water cement ratio of 0.70, show values between 600 and 700 psi. for 28-day flexural strength, and 3000 to 4000 psi. for 28-day compressive strength. Similar tests on specimens in which Ohio River

TABLE I.

THE EFFECT OF VARIOUS AGGREGATE COMBINATIONS ON DURABILITY AND CRACKING.

Miles surveyed	Age, yr.	Coarse Aggregate	Fine Aggregate	Broken area, sq. yd. per mile	Settled area, sq. yd. per mile	Re-placed area, sq. yd. per mile	Re-main-ing miles	Trans-verse crack Inter-val, ft.	Trans-verse cracks raveled and spalled, per cent	Trans-verse cracks Pro-gressive scale, per cent	Trans-verse cracks with map cracks, per cent	Map crack area, sq. yd. per mile	Pro-gressive scaled area, sq. yd. per mile	Checked area, sq. yd. per mile	Longi-tudinal crack, lin. ft. per mile	In-ternal corner breaks, per mile	Ex-ternal corner breaks, per mile	Blow-ups per mile
2.66	4	Tennessee River gravel	O.R.B.T sand			14	2.66	24.8	2.5	16.6	11.1				6	2.6	1.5	0.8
28.77	5			115			28.52	25.1	8.0	16.9	7.6	120	3	132	111	9.7	2.9	3.4
15.97	7			35			15.92	35.6	2.8	28.7	6.2	92			57	7.6	1.5	12.4
23.21	7½			37	4	10	23.08	43.7	6.5	30.1	3.3	16	3	10	97	5.1	1.2	4.2
19.35	8			702			18.18	32.6	14.4	33.4	5.6	17	14		934	3.5	2.5	4.0
1.23	9					78	1.22	17.8	16.1	23.5	11.1	2023	182		98	1.6	2.5	12.3
5.10	7	Tennessee River gravel	Ohio River sand	1707		557	4.01	16.9	1.0	57.1	4.0	372	239		1029	2.2	1.2	4.7
8.91	8			53	22	17	8.83	32.3	14.6	48.4	5.1	137	61		37	4.2	2.2	2.5
9.86	4	Crushed limestone	O.R.B.T sand				9.86	104.7	1.1						2	0.1		
22.15	5						22.15	101.5	19.5	2.0						1.1	0.1	
10.12	6						10.12	107.7	24.1						5	0.5		
5.89	7						5.89	110.0	6.1						6	1.0	0.7	
6.90	5½	Crushed limestone	Ohio River sand				6.90	98.0	31.4	20.7					4	0.9		
6.98	7						6.98	100.7	10.0						18	0.4	1.4	
2.50	7½						2.50	94.3	50.0	4.0					30	0.4		
2.56	4½	Ohio River gravel	Ohio River sand				1.64	22.3	5.1	3.6					73	1.8	0.6	
17.94	5					30	17.88	32.7	7.0	7.4	0.4				13	1.7	0.5	0.6
16.57	5½			3			16.57	39.1	8.2	3.2	0.3				23	2.4	0.4	0.8
25.06	7			3	4		25.05	43.0	15.6	23.6	0.2				58	1.0	0.3	2.0
14.65	8			36	3	3	14.59	36.9	11.0	20.0	1.8	3		65	42	1.1	0.4	1.2
18.29	10	Crushed sandstone	Crushed sandstone	27		156	17.92	49.5	13.2	83.6	1.0	1	100		37	2.2	0.7	0.4
7.43	11	Crushed sandstone	Ohio River sand	55	13	31	7.35	52.5	15.8	11.9					165	0.9	2.3	

All projects Bates type pavement, all projects on loam subsoils of western Kentucky except sandstone projects.

gravel or crushed limestone are incorporated show results practically the same.

Aggregate Research Program

For the purpose of the coarse aggregate research program laboratory tests were made on representative samples of crushed limestone, Ohio, Tennessee, and Cumberland River Gravel. Mineralogical analyses of these aggregates are shown in Table III.

Approximately 90 per cent of Tennessee and Cumberland River gravel is chert. Geological definitions of chert vary; however the most widely used defines

TABLE II.

PROPERTIES OF AGGREGATES FROM REPRESENTATIVE SOURCES.

All tests are Prevailing A.S.T.M. Standards or Tentative Standards.

	Cumberland River Gravel	Ohio River Gravel	Tennessee River Gravel	Lime-stone
Deval abrasion[a]	10.5	5.6	8.4	5.7
Los Angeles abrasion[b]		25.5	19.0	27.9
Soundness 5 alter. Sodium sulfate, per cent weight loss[b]		3.7		12.1
Soundness 5 alter. Sodium sulfate ledge rock method[a]	O.K.	O.K.	O.K.	O.K.

[a] Average of tests 1928 to 1938.
[b] Average of 30 tests on each aggregate.

TABLE III.

ANALYSIS OF AGGREGATES FROM REPRESENTATIVE SOURCES.

NOTE.—Analysis per cent by weight. The sandstones have iron oxide, silica, calcium, carbonate, or clay cementing material.

Tennessee River Gravel Mineralogical

Sound chert	64.7
Weathered chert	28.8
Quartz	1.4
Quartzite	3.1
Sandstone	2.0

Ohio River Gravel Mineralogical

Granite	34.8
Quartzite	17.9
Sound chert	12.1
Basalt-Diorite	11.8
Sandstone	11.8
Ferromagnesiums	6.5
Quartz	2.8
Limestone	2.3

Cumberland River Gravel Mineralogical

Sound chert	89.5
Weathered chert	1.9
Quartz	2.7
Quartzite	3.7
Sandstone	2.2

Limestone Quantitative

$CaCO_3$	91.40
$MgCO_3$	5.90
SiO_2	1.68
R_2O_3	0.88

it as an impure flint and jasper with crystals of pyrite and other foreign material. The color varies from white to gray such as found in the Golden Pond area of western Kentucky. Chert gravel obtained in the western Kentucky area is extremely porous, highly absorptive, and has a low specific gravity. Comparative bulk specific gravity tests, A. S. T. M. Tentative Methods C 127—36 T,[3] section 6, and 3-hr. boiling water absorption tests, A. S. T. M. Standard Method C 95—36,[4] are shown in Table IV.

TABLE IV.
COMPARATIVE SPECIFIC GRAVITY AND ABSORPTION TESTS.
Average of 1937-1938 Tests.

Source of Material	Bulk Specific Gravity	Absorption, 3 hr. Boiling Water, per cent
Ohio River, Carrollton, Ky.	2.68	0.7
Ohio River, Louisville, Ky.	2.65	0.8
Ohio River, below mouth Green River	2.54	2.4
Tennessee River, 20 miles upstream from mouth	2.34	5.3
Tennessee River, 5 miles upstream from mouth	2.32	5.5
Cumberland River, Clarksville, Tenn.	2.44	3.5
Limestone, Lexington, Ky.	2.70	0.3

In addition to the tests described above, the behavior of the four types of coarse aggregate when incorporated in concrete beams and subjected to freezing and thawing was investigated. Properties of the aggregates used in the tests are shown in Table V.

TABLE V.
PROPERTIES OF AGGREGATES USED IN FREEZING-AND-THAWING TESTS OF CONCRETE BEAMS.

Material	Bulk Specific Gravity	Absorption, 3 hr. Boiling Water, per cent	Los Angeles Abrasion (A.S.T.M. C131-38 T)	Deval Abrasion (A.S.T.M.; Stone D 2-33, Gravel D 289-37 T)	Soundness 5 Alter. Sodium Sulfate (A.S.T.M. C 89-37 T Ledge Rock Method)
Tennessee River Gravel	2.33	5.4	19.2	7.6	O.K.
Cumberland River Gravel	2.45	3.8	--	9.8	O.K.
Ohio River Gravel	2.67	0.6	20.1	5.4	O.K.
Crushed Limestone	2.70	0.3	26.8	6.0	O.K.

[3] Tentative Method of Test for Specific Gravity and Absorption of Coarse Aggregate (C 127 - 36 T). *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 805 (1936); also 1938 Book of A.S.T.M. Tentative Standards, p. 651.

[4] Standard Method of Test for Absorption by Aggregates for Concrete (Laboratory Determinations) (C 95 - 36), 1936 Book of A.S.T.M. Standards, Part II, p. 330.

One shipment of portland cement meeting the usual requirements was used in all beams. Fine aggregate used throughout the tests was obtained from the Ohio River below the mouth of the Tennessee River, and had the following properties:

Bulk specific gravity	2.62
Sieve Analysis, per cent:	
Passing ⅜ in. sieve	100.0
Passing No. 4 sieve	99.9
Passing No. 16 sieve	66.0
Passing No. 50 sieve	10.4
Passing No. 100 sieve	3.0

The concrete used in the beams was specified as follows:

Cement factor: 1.5 bbl. per cu. yd. concrete.
Water-cement ratio: 5.75 gal. per sack, correction made for moisture content of aggregate.
Sand in combined fine and coarse aggregates, per cent by weight: gravel mix, 35; limestone mix, 38.
Slump, in.: 1 to 2½.
Maximum size coarse aggregate, in.: 2½.
Molding test specimens: Rodded 50 times per square foot of area A.S.T.M. Method C 78 - 38.[5]
Curing: 7 days burlap and water at 70 F., 7 days in air.
Size: 6 by 6 by 42-in. beams.
Number of beams: 8 from each type aggregate.

The concrete beams were subjected to freezing and thawing after a 14-day curing period, because this period approximates certain field conditions. The beams were immersed in water, and subjected to a freezing period of 16 hr. at a temperature between −5 F. and −10 F. After the freezing period the beams were thawed in water at 70 F. for a period of 8 hr. Flexural tests were made on the concrete beams at 14 and 28 days, and also after 40 cycles of freezing and thawing. Comparative results of these tests are shown in Table VI.

Concrete pavement constructed of chert gravel obtained in western Kentucky shows signs of disintegration after exposure to actual weathering conditions for a period as short as one year. Beams manufactured from this aggregate show a decrease in flexural strength from 35 to 100 per cent when subjected to 40 cycles of freezing and thawing in the presence of water. The void space in aggregate particles and concrete has long been recognized as an important factor in the durability of concrete. Highly absorptive concrete is subject to rapid disintegration and failure when exposed to weathering conditions. Chert gravel concrete has an absorption approximately twice that of the same concrete in which crushed limestone or Ohio River gravel is incorporated. Varying the moisture content and temperature of chert gravel concrete produces large vol-

[5] Standard Method of Test for Flexural Strength of Concrete (Laboratory Method Using Simple Beam with Third Point Loading) (C 78 - 38), 1938 Supplement to Book of A.S.T.M. Standards, p. 119.

TABLE VI.
SHOWING REDUCTION IN FLEXURAL STRENGTH OF CONCRETE AFTER 40 CYCLES OF FREEZING AND THAWING.

Fine Aggregate	Coarse Aggregate	Modulus of Rupture, 14 days, psi.[a]	Modulus of Rupture, 28 days, psi.[a]	Absorption of Concrete, per cent	Modulus of Rupture, psi., 14-day beams After 40 cycles Freezing and Thawing[b]	Absorption of Concrete After 40 cycles Freezing and Thawing, per cent	Reduction in Modulus of Rupture After 40 cycles Freezing and Thawing, per cent
O.R.B.T. sand	Tennessee River gravel	582	637	7.6	0	8.7	100.0
	Cumberland River gravel	693	710	4.6	431	7.8	37.8
	Ohio River gravel	763	810	3.5	610	4.2	20.0
	Limestone	795	860	2.9	745	3.8	6.3

a Represents average of 6 tests on each aggregate.
b Represents average of 4 tests on each aggregate.

ume changes, due to the confined moisture and the expansive nature of the aggregate. The bond is broken permitting increased absorption and volume changes; thus general structural failure results.

Conclusions

Based on the investigation outlined, the following conclusions have been drawn. The influencing factors are necessarily those found in our state.

1. The failure of concrete pavement throughout the western part of the State was due to the use of chert gravel obtained from the Tennessee and Cumberland Rivers in western Kentucky.

2. With the present methods of pavement construction, this chert gravel will not produce durable pavement.

3. Chert gravel found to produce unsatisfactory pavement in Kentucky may be eliminated by two specifications:

(a) Coarse aggregate shall not show an absorption greater than 3 per cent when subjected to A. S. T. M. Standard Test C 95—36.

(b) Concrete in which any aggregate is incorporated shall not show a reduction in flexural strength greater than 30 per cent when subjected to 40 cycles of freezing and thawing in the presence of water.

4. Tennessee or Cumberland River sand will produce durable pavement when used with Ohio River gravel or crushed limestone.

5. The use of sandstone as both fine and coarse aggregate resulted in unsatisfactory pavement.

6. The use of sandstone and Ohio River sand as aggregates resulted in satisfactory pavement.

Revised Simplified Practice Recommendation R163-36, Coarse Aggregates, Approved by Industry

THE current revision of Simplified Practice Recommendation R163-36, Coarse Aggregates (crushed stone, gravel and slag), has been accorded the required degree of acceptance by the industry, and has been approved for promulgation, according to an announcement by the Division of Simplified Practice, National Bureau of Standards. The revised recommendation will be identified as Simplified Practice Recommendation R163-39.

This recommendation was first promulgated in 1936. At that time, two groups of sizes with the same overall range, but with different intermediate size ranges, were recommended. Each group was intended to be substantially complete and only one was intended to be used in any single marketing area. The Joint Committee of the Mineral Aggregates Associations in submitting this plan recognized the disadvantage of having two groups, but pointed out that when wide acceptance of the recommended sizes had been obtained effort could be made to consolidate the two groups.

As a result of experience gained since 1936 the Standing Committee was able to achieve the desired consolidation of sizes into one group, and thus effect a net elimination of 12 sizes. The revision, like the original, comprises primary sizes and their combinations or modifications, but closer tolerances have been fixed for the lower limits of each size; a 5 per cent limit having been placed on a size smaller than the nominal minimum to further control the amount of fine material. One size was added to meet a growing demand for fine seal construction for surface treatment of airports and for other surfaces requiring a fine seal material.

Until printed copies are available, mimeographed copies of this Simplified Practice Recommendation may be obtained without charge from the Division of Simplified Practice, National Bureau of Standards, Washington, D. C.

The National Crushed Stone Association Safety Competition of 1938

By T. D. LAWRENCE and
E. E. GETZIN

Under Supervision of W. W. Adams,
Employment Statistics Section,
Mineral Production and Economics Division,
U. S. Bureau of Mines.

• **Port Inland Limestone Quarry of the Inland Lime and Stone Company Wins Safety Contest.**

THE thirteenth annual safety contest conducted by the Bureau of Mines in cooperation with the National Crushed Stone Association, which has just been completed, shows a decided improvement in the accident record of the enrolled companies as compared with that of the companies enrolled in the preceding year. All of the enrolled companies were members of the National Crushed Stone Association.

Combined records covering 50 plants competing in the 1938 contest showed a reduction of 45 per cent in the number of accidents and 58 per cent in the number of days lost from accidents when compared with similar records covering the same number of plants in 1937, although the number of man-hours worked declined only 24 per cent. The accident-frequency rate for 47 open quarries and 3 underground mines enrolled in 1938 was 17.2 per million man-hours of employment, and the severity rate was 4.4 per thousand man-hours. Corresponding rates were 23.6 and 8.0, respectively, for 47 open quarries and 3 underground mines enrolled in 1937. The frequency rate in 1938 was the lowest and best on record during the 13-year period during which the annual safety contests have been conducted.

Since only a few underground mines are entered each year, it is not possible to compare the open-quarry group with the underground group for a single year. However, the average frequency-rate for open quarries over a 13-year period, as shown in tables 3 and 4, was 22 per cent lower than that for underground mines, and the average severity-rate was 11 per cent lower.

The award for 1938 was won by the Port Inland limestone quarry in Mackinac County, Michigan. This plant was operated by the Inland Lime and Stone Company and worked 299,751 man-hours without a disabling injury.

A certificate of honorable mention will be awarded to each plant, except the trophy winner, that operated during the year with an accident-free record. In addition to the winner, there were 21 such plants in 1938; 20 open quarries and one underground mine. The plants to be awarded these cerficates are:

EMPLOYEES AT THE CRUSHING AND SCREENING PLANT OF THE PORT INLAND LIMESTONE QUARRY, INLAND LIME AND STONE COMPANY, MANISTIQUE, MICHIGAN, WINNER OF THE N. C. S. A. SAFETY CONTEST FOR 1938.

TABLE 1.

RELATIVE STANDING OF PLANTS IN THE 1938 NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, BASED UPON THE ACCIDENT-SEVERITY RATES OF THE PLANTS (QUARRY GROUP)[1]

Code No.	Group No.	Hours worked	Number of accidents[2] Fatal	P.T.	P.P.	Temp.	Total	Number of days of disability[2] Fatal	P.T.	P.P.	Temp.	Total	Frequency rate[3]	Severity rate[3]
1	1	299,751	----	----	----	----	----	----	----	----	----	----	0.000	0.000
2	2	242,477	----	----	----	----	----	----	----	----	----	----	.000	.000
3	3	215,437	----	----	----	----	----	----	----	----	----	----	.000	.000
4	4	129,871	----	----	----	----	----	----	----	----	----	----	.000	.000
5	5	120,642	----	----	----	----	----	----	----	----	----	----	.000	.000
6	6	94,421	----	----	----	----	----	----	----	----	----	----	.000	.000
7	7	91,730	----	----	----	----	----	----	----	----	----	----	.000	.000
8	8	81,102	----	----	----	----	----	----	----	----	----	----	.000	.000
9	9	77,874	----	----	----	----	----	----	----	----	----	----	.000	.000
10	10	69,458	----	----	----	----	----	----	----	----	----	----	.000	.000
12	11	51,835	----	----	----	----	----	----	----	----	----	----	.000	.000
13	12	49,958	----	----	----	----	----	----	----	----	----	----	.000	.000
14	13	47,312	----	----	----	----	----	----	----	----	----	----	.000	.000
15	14	39,178	----	----	----	----	----	----	----	----	----	----	.000	.000
16	15	37,192	----	----	----	----	----	----	----	----	----	----	.000	.000
17	16	35,058	----	----	----	----	----	----	----	----	----	----	.000	.000
18	17	31,794	----	----	----	----	----	----	----	----	----	----	.000	.000
19	18	24,483	----	----	----	----	----	----	----	----	----	----	.000	.000
20	19	24,227	----	----	----	----	----	----	----	----	----	----	.000	.000
21	20	18,645	----	----	----	----	----	----	----	----	----	----	.000	.000
22	21	8,414	----	----	----	----	----	----	----	----	----	----	.000	.000
23	22	57,917	----	----	----	1	1	----	----	----	3	3	17.266	.052
24	23	149,825	----	----	----	2	2	----	----	----	9	9	13.349	.060
25	24	74,945	----	----	----	1	1	----	----	----	5	5	13.343	.067
26	25	230,849	----	----	----	2	2	----	----	----	19	19	8.664	.082
27	26	63,986	----	----	----	1	1	----	----	----	6	6	15.628	.094
28	27	72,291	----	----	----	2	2	----	----	----	8	8	27.666	.111
29	28	14,326	----	----	----	1	1	----	----	----	2	2	69.803	.140
31	29	51,955	----	----	----	1	1	----	----	----	9	9	19.247	.173
32	30	74,477	----	----	----	1	1	----	----	----	18	18	13.427	.242
33	31	64,449	----	----	----	4	4	----	----	----	35	35	62.065	.543
34	32	132,948	----	----	----	4	4	----	----	----	79	79	30.087	.594
35	33	131,043	----	----	----	1	1	----	----	----	88	88	7.631	.672
36	34	62,285	----	----	----	3	3	----	----	----	44	44	48.166	.706
38	35	63,739	----	----	----	1	1	----	----	----	92	92	15.689	1.443
39	36	213,048	----	----	----	8	8	----	----	----	330	330	37.550	1.549
40	37	177,358	----	----	1	----	1	----	----	300	----	300	5.638	1.691
41	38	109,755	----	----	----	3	3	----	----	----	231	231	27.334	2.105
42	39	168,322	----	----	----	5	5	----	----	----	389	389	29.705	2.311
43	40	89,056	----	----	1	----	1	----	----	300	----	300	11.229	3.369
44	41	217,156	----	----	----	24	24	----	----	----	734	734	110.520	3.380
45	42	87,628	----	----	----	3	3	----	----	----	302	302	34.236	3.446
46	43	40,540	----	----	1	----	1	----	----	300	----	300	24.667	7.400
47	44	59,467	----	----	1	1	2	----	----	600	29	629	33.632	10.577
48	45	255,747	----	----	2	5	7	----	----	5,100	575	5,675	27.371	22.190
49	46	120,317	1	----	----	2	3	6,000	----	----	177	6,177	24.934	51.339
50	47	83,831	1	----	----	----	1	6,000	----	----	----	6,000	11.929	71.573
Totals and rates, 1938		4,658,119	2	0	6	76	84	12,000	0	6,600	3,184	21,784	18.033	4.677
Totals and rates, 1937		6,199,001	7	0	9	136	152	42,000	0	5,875	4,461	52,336	24.520	8.443

[1] As the accident reports from mining companies are considered confidential by the Bureau of Mines, the identities of the plants to which this table relates are not revealed.

[2] P. T. means permanent total disability; P. P. means permanent partial disability; and Temp. means temporary disability.

[3] Frequency rate indicates number of fatal, permanent, and other lost-time accidents per million man-hours of exposure; severity rate indicates number of days lost from accidents per thousand man-hours.

1.—Krause No. 1 limestone quarry, St. Clair County, near Columbia, Monroe County, Illinois, operated by the Columbia Quarry Company. The quarry worked 242,477 man-hours in 1938.

2.—Woodleaf granite quarry, Woodleaf, Rowan County, North Carolina, operated by the Raleigh Granite Company, a division of the Southern Aggregates Corporation. The quarry worked 215,437 man-hours in 1938.

3.—Piqua limestone quarry, Piqua, Miami County, Ohio, operated by the Ohio Marble Company. The quarry worked 129,871 man-hours in 1938.

4.—North Branford No. 7 trap-rock quarry, North Branford, New Haven County, Connecticut, operated by the New Haven Trap Rock Company. The quarry worked 120,642 man-hours in 1938.

5.—Rolesville granite quarry, Wake Forest, Wake County, North Carolina, operated by the Raleigh Granite Company, a division of Southern Aggregates Corporation. The quarry worked 94,421 man-hours in 1938.

Supervisory Safety Organization, Inland Lime and Stone Co., Manistique, Michigan.

6.—White Haven sandstone quarry, White Haven Luzerne County, Pennsylvania, operated by the General Crushed Stone Company. The quarry worked 91,730 man-hours in 1938.

7.—LeRoy limestone quarry, LeRoy, Genesee County, New York, operated by the General Crushed Stone Company. The quarry worked 81,102 man-hours in 1938.

8.—Winchester trap-rock quarry, Winchester, Middlesex County, Massachusetts, operated by the General Crushed Stone Company. The quarry worked 77,874 man-hours in 1938.

9.—Marquette limestone quarry, Cape Girardeau, Cape Girardeau County, Missouri, operated by the Marquette Cement Mfg. Company. The quarry worked 69,458 man-hours in 1938.

10.—Pixley limestone mine, Independence, Jackson County, Missouri, operated by the Steward Sand and Material Company. The mine worked 53,245 man-hours in 1938.

11.—Jordanville limestone quarry, Jordanville, Herkimer County, New York, operated by the General Crushed Stone Company. The quarry worked 51,833 man-hours in 1938.

12.—Union limestone quarry, Hillsville, Lawrence County, Pennsylvania, operated by the Union Limestone Company. The quarry worked 49,958 man-hours in 1938.

13.—Gasport limestone quarry, Gasport, Niagara County, New York, operated by the Wickwire Spencer Steel Company. The quarry worked 47,312 man-hours in 1938.

14.—Catskill limestone quarry, Catskill, Green County, New York, operated by the North American Cement Corporation. The quarry worked 39,178 man-hours in 1938.

15.—Middlefield No. 1 trap-rock quarry, New Haven County, near Middlefield, Middlesex County,

Quarry Employees of the Port Inland Limestone Quarry of the Inland Lime and Stone Company, Manistique, Michigan, Winner of the N. C. S. A. Safety Contest for 1938.

TABLE 2.

RELATIVE STANDING OF PLANTS IN THE 1938 NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, BASED UPON THE ACCIDENT-SEVERITY RATES OF THE PLANTS (UNDERGROUND-MINE GROUP)[1]

Code No.	Group No.	Hours worked	Number of accidents[2]					Number of days of disability[2]					Frequency rate[3]	Severity rate[3]
			Fatal	P.T.	P.P.	Temp.	Total	Fatal	P.T.	P.P.	Temp.	Total		
11	1	53,245	----	----	----	----	----	----	----	----	----	----	0.000	0.000
30	2	189,629	----	----	----	1	1	----	----	----	32	32	5.273	.169
37	3	91,548	----	----	----	1	1	----	----	----	101	101	10.923	1.103
Totals and rates, 1938		344,422	0	0	0	2	2	0	0	0	133	133	5.980	.398
Totals and rates, 1937		364,680	0	0	0	3	3	0	0	0	91	91	8.226	.250

[1] As the accident reports from mining companies are considered confidential by the Bureau of Mines, the identities of the plants to which this table relates are not revealed.

[2] P. T. means permanent total disability; P. P. means permanent partial disability; and Temp. means temporary disability.

[3] Frequency rate indicates number of fatal, permanent, and other lost-time accidents per million man-hours of exposure; severity rate indicates number of days lost from accidents per thousand man-hours.

YEARLY SUMMARY—NATIONAL CRUSHED STONE ASSOCIATION SAFETY CONTEST, 1926-1938

TABLE 3. OPEN QUARRIES

Year	Plants	Hours worked	Number of accidents[1]					Number of days of disability[1]					Frequency rate[2]	Severity rate[2]
			Fatal	P.T.	P.P.	Temp.	Total	Fatal	P.T.	P.P.	Temp.	Total		
1925[3]	38	4,927,402	4	----	3	292	299	24,000	----	3,600	5,286	32,886	60.681	6.674
1926	40	5,298,983	3	----	6	207	216	18,000	----	9,000	4,239	31,239	40.763	5.895
1927	48	7,876,791	9	----	2	458	469	54,000	----	2,100	7,186	63,286	59.542	8.034
1928	53	7,509,098	8	----	4	322	334	48,000	----	8,700	5,493	62,193	44.479	8.282
1929	53	7,970,325	4	----	5	286	295	24,000	----	5,760	5,533	35,293	37.012	4.428
1930	68	8,013,415	6	----	9	227	242	36,000	----	7,250	3,671	46,921	30.199	5.855
1931	58	5,085,857	4	----	13	198	215	24,000	----	18,660	3,540	46,200	42.274	9.084
1932	40	2,661,850	1	----	4	75	80	6,000	----	6,750	2,481	15,231	30.054	5.722
1933	40	2,704,871	1	----	1	67	69	6,000	----	48	2,893	8,941	25.510	3.306
1934	46	3,288,257	1	----	2	106	109	6,000	----	2,850	1,873	10,723	33.148	3.261
1935	46	4,166,306	2	1	8	77	88	12,000	6,000	9,900	3,015	30,915	21.122	7.420
1936	50	6,399,023	5	----	14	182	201	30,000	----	8,168	4,590	42,758	31.411	6.682
1937	47	6,199,001	7	----	9	136	152	42,000	----	5,875	4,461	52,336	24.520	8.443
1938	47	4,658,119	2	----	6	76	84	12,000	----	6,600	3,184	21,784	18.033	4.677
Total 1926-38		71,831,896	53	1	83	2,417	2,554	318,000	6,000	91,661	52,159	467,820	35.555	6.513
Total 1925-38		76,759,298	57	1	86	2,709	2,853	342,000	6,000	95,261	57,445	500,706	37.168	6.523

TABLE 4. UNDERGROUND MINES

Year	Plants	Hours worked	Fatal	P.T.	P.P.	Temp.	Total	Fatal	P.T.	P.P.	Temp.	Total	Frequency rate[2]	Severity rate[2]
1925[3]	3	400,672	----	----	----	29	29	----	----	----	228	228	72.378	0.569
1926	3	517,926	----	----	----	34	34	----	----	----	533	533	65.646	1.029
1927	2	318,449	1	----	1	14	16	6,000	----	300	68	6,368	50.244	19.997
1928	5	542,193	1	----	1	68	70	6,000	----	300	888	7,188	129.105	13.257
1929	4	665,520	1	----	1	30	32	6,000	----	300	617	6,917	48.083	10.393
1930	6	595,367	1	----	1	15	17	6,000	----	225	468	6,693	28.554	11.242
1931	3	345,105	----	----	----	4	4	----	----	----	147	147	11.591	.426
1932	2	158,450	----	----	----	6	6	----	----	----	165	165	37.867	1.041
1933	3	229,381	----	----	----	11	11	----	----	----	349	349	47.955	1.521
1934	4	248,146	----	----	----	13	13	----	----	----	287	287	52.389	1.157
1935	2	175,994	----	----	----	3	3	----	----	----	249	249	17.046	1.415
1936	4	334,747	1	----	----	7	8	6,000	----	----	117	6,117	23.899	18.274
1937	3	364,680	----	----	----	3	3	----	----	----	91	91	8.226	.250
1938	3	334,442	----	----	----	2	2	----	----	----	133	133	5.980	.398
Total 1926-38		4,830,380	5	0	4	210	219	30,000	0	1,125	4,112	35,237	45.338	7.295
Total 1925-38		5,231,052	5	0	4	239	248	30,000	0	1,125	4,340	35,465	47.409	6.780

[1] P. T. means permanent total disability; P. P. means permanent partial disability; and Temp. means temporary disability.

[2] Frequency rate indicates number of fatal, permanent, and other lost-time accidents per million man-hours of exposure; severity rate indicates number of days lost from accidents per thousand man-hours.

[3] The National Crushed Stone Association safety contest began in 1926; figures for 1925 for company members are given for comparison.

Connecticut, operated by the New Haven Trap Rock Company. The quarry worked 37,192 man-hours in 1938.

16.—Reidsville granite quarry, Reidsville, Rockingham County, North Carolina, operated by the Raleigh Granite Company, a division of the Southern Aggregates Corporation. The quarry worked 35,058 man-hours in 1938.

17.—Cheshire No. 6 trap-rock quarry, West Cheshire, New Haven County, Connecticut, operated by the New Haven Trap Rock Company. The quarry worked 31,794 man-hours in 1938.

18.—McCoy limestone quarry, Bridgeport, Montgomery County, Pennsylvania, operated by the Warner Company. The quarry worked 24,483 man-hours in 1938.

19.—Rocky Hill trap-rock quarry, Rocky Hill, Hartford County, Connecticut, operated by the New Haven Trap Rock Company. The quarry worked 24,227 man-hours in 1938.

20.—Howes Cave limestone quarry, Howes Cave, Schoharie County, New York, operated by the North American Cement Corporation. The quarry worked 18,645 man-hours in 1938.

21.—No. 4 trap-rock quarry, Knippa, Uvalde County, Texas, operated by the Southwest Stone Company. The quarry worked 8,414 man-hours in 1938.

The following nineteen States were represented in the National Crushed Stone Association Safety Contest of 1938:

California	North Carolina
Connecticut	Ohio
Georgia	Oklahoma
Illinois	Pennsylvania
Maryland	South Carolina
Massachusetts	Tennessee
Michigan	Texas
Minnesota	Virginia
Missouri	West Virginia
New York	

During the year there were 84 disabling injuries at the 47 open quarries enrolled in the contest. Of these, only 2 were fatal; they were charged with 6,000 days of disability each as required by the contest rules. The total time loss chargeable to all accidents during the year was 21,784 days. The accident-frequency rate of 18.0 accidents per million man-hours and the accident-severity rate of 4.7 days lost per thousand man-hours were calculated from a total volume of employment of 4,658,119 man-hours worked during the year.

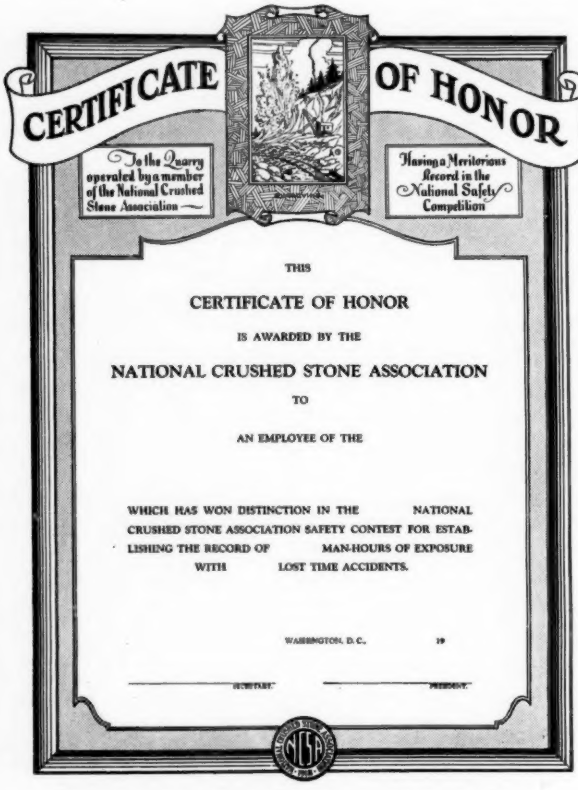
The 21 open quarries which operated throughout the year without a disabling injury worked a total of 1,790,859 man-hours, or 38 per cent of the total man-hours covered by the open-quarry group of the contest. Accident-free plants, during 1937, accounted for only 16 per cent of the total man-hours worked in the open quarries.

The average number of days charged to accidents that occurred at the 47 open quarries enrolled in the contest in 1938 was 259 per accident, and the average

TABLE 5.
AVERAGE LENGTH OF DISABILITY FOR TEMPORARY INJURIES AT PLANTS ENROLLED IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION

	Underground mines			Open quarries			Total		
Year	No. of temporary accidents	No. of days of disability	Aver. length of disability (days)	No. of temporary accidents	No. of days of disability	Aver. length of disability (days)	No. of temporary accidents	No. of days of disability	Aver. length of disability (days)
1925	29	228	8	292	5,286	18	321	5,514	17
1926	34	533	16	207	4,239	20	241	4,772	20
1927	14	68	5	458	7,186	16	472	7,254	15
1928	68	888	13	322	5,493	17	390	6,381	16
1929	30	617	21	286	5,533	19	316	6,150	19
1930	15	468	31	227	3,671	16	242	4,139	17
1931	4	147	37	198	3,540	18	202	3,687	18
1932	6	165	28	75	2,481	33	81	2,646	33
1933	11	349	32	67	2,893	43	78	3,242	42
1934	13	287	22	106	1,873	18	119	2,160	18
1935	3	249	83	77	3,015	39	80	3,264	41
1936	7	117	17	182	4,590	25	189	4,707	25
1937	3	91	30	136	4,461	33	139	4,552	33
1938	2	133	67	76	3,184	42	78	3,317	43
Total	239	4,340	18	2,709	57,445	21	2,948	61,785	21

length of disability from temporary injuries was 42 days per injury. Records for 38 plants in 1925, based on these same rules, show an average charge of 110 days for each accident and 18 days for each temporary injury. The trend over the past fourteen years at crushed stone plants has been for injuries to become fewer in number in proportion to the total



Presented to Each Employee of Each Plant Completing the Year with No Lost Time Accidents.

man-hours worked; on the other hand the average length of each injury has tended to become greater or more severe.

Tables 1 and 2 show the relative standing of each plant in the contest arranged according to its accident-severity rate. In cases where plants operated throughout the year without accidents, relative standing was determined by the number of man-hours worked. Tables 3, 4, and 5 show summary figures for each contest covering a period from 1926 to 1938 and for Association members for 1925, the year before the contests were started.

October 3 "Construction Day" at New York World's Fair

TUESDAY, October 3, has been designated as "Construction Day" at the New York Fair.

A program on the theme "Building Progress in the Word of Tomorrow" will be given in the morning of that day at the Hall of Special Events. Stephen F. Voorhees, chairman of the World's Fair Board of Design and vice president of New York World's Fair 1939, Inc., former president of the American Institute of Architects, and first president of the New York Building Congress, Inc., will preside. Participating speakers who have accepted to date include: Colonel John P. Hogan, Robert D. Kohn, Bassett Jones and Walter Dorwin Teague.

W. H. Wallace Becomes Head of Wallace Stone Company

MR. W. H. WALLACE, former Secretary-Treasurer of The Wallace Stone Company, Bay Port, Michigan, has been made President of that Company to succeed his brother, Mr. R. N. Wallace, retiring because of ill health. The latter, it will be recalled, was elected to membership on the Board of Directors of the National Association at the Annual Convention last January. Mr. G. A. Carrington of Bay Port, has become Secretary-Treasurer of the Company.

John Wunder

IT IS with real sorrow that his many friends throughout the crushed stone industry will learn of the death of John Wunder, President of the Trap Rock Company, Minneapolis, which occurred in Minneapolis on July 21. Through the early days of the Association, Mr. Wunder was a familiar figure, at our Annual Conventions and at meetings of the Board of Directors, on which body he served for many years.

Mr. Wunder was of great assistance both morally and financially in the upbuilding of the Association, and it can be truthfully said that our officers never turned to him for help in vain.

Our sincere sympathy is extended to those close to him as well as to his Company for the loss they have suffered by his passing.

John Carmody Becomes First Administrator of Federal Works Agency

• **Under President's Reorganization Plan, Bureau of Public Roads is shifted from Department of Agriculture to newly created Federal Works Agency and will be designated in the future as Public Roads Administration.**

"ROADS are not used too much, they're used too little. There's not enough of them. They're not good enough—not safe enough! They don't keep pace with automotive output!"

These sentiments are of particular interest to every Road Builder, since they were expressed by John Michael Carmody, first administrator of the newly created Federal Works Agency, which houses the Public Roads Administration. Administrator Carmody voiced his views and his plans in an exclusive interview with Robert E. Harper, director of public relations for the American Road Builders' Association.

"I know that tourism is fast becoming one of this country's top-flight industries," he declared. "It is already number one in several states. I am glad that this condition exists. People live only once and I see no reason why all of them, youngsters and oldsters alike, should not become better acquainted with the 'greener pastures' beyond the horizons of their own surroundings. Our 48 states abound with points of natural beauty and historic interest. Good roads, properly maintained, make these scenic attractions accessible to all our citizens.

"I believe that safe highways can be provided for the comfortable, convenient and safe use of the ever-increasing legions of highway users by applying the principle of modern engineering. I'm for obtaining rights-of-way on a much larger scale. I'm for extensive roadside development and highway beautification. I'm for space annihilation with safety on our highways. The main reason why people use planes is to save time in travel. Highways must eventually provide the same facility."

Before assuming his new post, Mr. Carmody was for two years administrator of the Rural Electrification Administration. In this job, he pointed out, "the chief deterrent to the progress of our schedule to string so many miles of line a day was the lack of passable roads in rural areas. We must not lose sight of the fact that, in addition to the improvement of our major highways, we still have the problem on our hands of lifting rural America out the mud."

Emphasizing the value of roads as an unemployment cure, he declared, "The construction of new highways will put thousands of our unemployed back to work on the most worth while of public projects. The employment of these workers will create additional demands for labor and will provide the incentive for outside agencies to invest additional funds. New highway construction will put more men to work, in more places, faster and with greater returns for the worker and taxpayer for each dollar spent than any other public enterprise.

"As to the new endeavor that lies just ahead, it is not my plan to set up at the top one iota of duplication of the work that is already being carried on by the various Federal Works Administration agencies. It is rather my desire to work through and with all existing agencies and to strive to retain within them all activities that are at present giving satisfaction and that are being handled efficiently. With respect to roads, we shall endeavor to maintain the same high standards that made the Bureau of Public Roads such a successful arm of the federal government. I have been impressed by the splendid research and laboratory work that is being carried on by the Bureau personnel under the efficient direction of Thomas H. MacDonald. This will, of course, be continued. We shall continue to search for better materials and methods with a restless determination and the results of our research will be put to public use to the best possible advantage within our allotted appropriations.

"So far as industry is concerned, we shall make every effort to acquaint all phases of industry depending on road building for a livelihood with our plans as far in advance as can be determined."

Another Instance of Unreliability of the Sodium Sulfate Soundness Test

By A. T. GOLDBECK

Engineering Director,
National Crushed Stone Association,
Washington, D. C.

THE sodium sulfate soundness test as applied to coarse aggregate is intended to be an accelerated test for determining the resistance of aggregate to the destructive influence of the weather. As freezing and thawing constitutes the most rapid weathering effect, the sodium sulfate soundness test may be said to be a test in which an attempt is made to simulate the destructive influence of freezing and thawing.

Stone for use in trickling filters is commonly required to withstand 20 cycles of the sodium sulfate test in accordance with the following procedure which is recommended by the Committee of the Sanitary Engineering Division of the American Society of Civil Engineers on Filtering Materials for Water and Sewage Works.

Recommended Procedure for the Sodium Sulfate Soundness Test

For the sample to be tested select not less than ten, and preferably twenty, pieces of the material of the size to be used on the work. This sample should be secured by quartering or dividing to the desired amount, but in any case at least three pieces of each type of material contained in the original stock must be included, such as dense or porous slag, or variations in color and texture of limestone, as noted in the quarry face. Examine each piece for fracture and cracks. Any loose fragments should be removed before the test is begun. Dry the sample at 100° to 105° C. for 4 hr. Weigh and identify each piece by marking it plainly with a number. Record the weights of the individual pieces as well as the total weight of this sample.

Prepare a saturated solution of sodium sulfate by adding anhydrous sodium sulfate (chemically pure, Na_2SO_4) to hot water (preferably distilled) at the rate of 400 grams per liter. The solution must be heated 30 min. at 29° to 33° C. (85° to 90° F.) with frequent stirrings to prevent caking in the bottom and to effect solution quickly. After this it must be set aside for at least 12 hr. to cool before use.

Immerse the dry sample, after it has been weighed and cooled to room temperature, in the saturated solution of sodium sulfate contained in an agate-ware or other suitable container, with cover to prevent evaporation loss, and of adequate capacity. A 3-qt. or a 4-qt. agate-ware kettle or dish, or a 1-gal. earthen-ware crock will serve acceptably.

Allow the immersed material to stand at room temperature or in an incubator maintained as close to 21° C. as possible. Variations in temperature should not exceed 5° above or below 21° C. A maximum and minimum thermometer placed in the testing room should be used to register daily fluctuations, which should be recorded with the test results. Crystals of the sodium sulfate must be present in the container at all times to assure a saturated solution.

After the completely covered sample has soaked in the sodium sulfate solution for 19 hr., remove the pieces one by one, and examine each carefully for any sign of disintegration, such as cracking, flaking, checking, splitting, or crumbling. The portions that can be removed with the fingers must be taken off, weighed, set aside, and calculated as percentage loss for that cycle.

After examination, the entire sample contained in a shallow pan or pans, should be placed in a previously heated drying oven and maintained for 4 hr. at a temperature of 100° to 105° C. On removal from the drying oven, the sample is allowed to cool for 1 hr. in the vicinity of the solution containers, and, at the end of the cooling period, it is immersed again in the sodium sulfate solution.

One cycle consists of 4 hr. of drying, 1 hr. of cooling, and 19 hr. of soaking, including the time for an examination of the material. The condition of each piece should be recorded after each cycle.

Repeat the treatment of drying, cooling, and soaking, for twenty cycles, or until obvious failure, when the identity of the original individual piece is lost, or the entire sample is shown to be unsound as hereinafter specified. If for any reason the continuity of the testing must be interrupted, as, for example, over

week-ends, the sample should remain in solution, but this extra day should not constitute a cycle.

At the end of the twenty cycles, wash the material thoroughly, boiling if necessary to remove all contained sodium sulfate. All fines should be saved. The sample should be sifted and a record made of the weight of all material greater than the minimum size specified, all between this size and 0.5 in. (No. 2 mesh), and all smaller than 0.5 in. (No. 2 mesh).

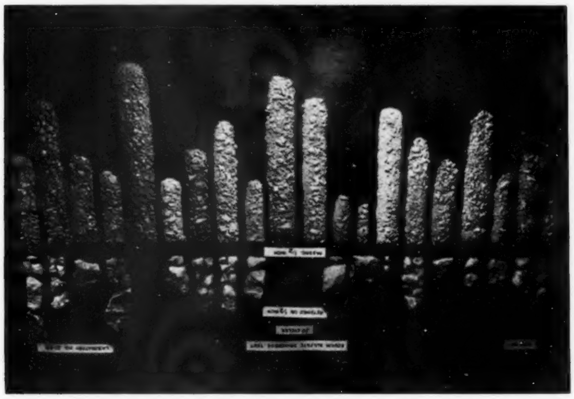


FIGURE 1.
Sample consisted originally of 50 pieces, all retained on 1½ in. sieve. After 20 cycles of sodium sulfate test, 49.9 per cent passed through the ½ in. sieve.

At the end of the test the percentage loss is computed in the following manner:

(a) Each piece of material is allotted a percentage determined by the total number of pieces making up the sample (that is, for 20 pieces in the sample, each piece would represent 5 per cent);

(b) An individual piece breaking into three or more parts, or which is so cracked that subsequent breakage is beyond question, is considered to have failed in the test, provided each such fragment is more than 10% of the original weight of the piece; and,

(c) The percentage by weight of chips, spalls, and flakes from the remaining pieces passing the 0.5 in. screen (No. 2 mesh) to the total original weight of the same pieces is considered as percentage lost.

The material as a whole is regarded as unsound if 10% of the pieces fail, or if the total weight of débris smaller than 0.5 in. exceeds 10 per cent.

In the past, we have had occasion to express doubt as to the real value of the sodium sulfate test and other investigators have brought forth instances which have indicated the test to be one which may give misleading results. The following is still another example which tends to indicate the doubtful value of the sodium sulfate test.

A trickling filter which had been in service for 25 years was dismantled recently to make way for a new sewage disposal plant. The stone in this trickling filter was a limestone having the following approximate characteristics:

Wt. per cu. ft.	Absorption lb./cu. ft.	Per cent Wear (Deval)	Toughness (per cent)
165	1.5	4.0 to 5.0	6 to 7

It will be seen that this material is relatively soft and yet it has given eminently satisfactory service throughout 25 years of exposure in the trickling filter.

Samples of this stone were procured and were subjected to 20 cycles of the sodium sulfate soundness test with the result as shown in Fig. 1. Of the original weight of 5290.1 gm., 2637.7 gm., or 49.9 per cent of the sample passed the ½ in. sieve after the test and could certainly be counted as "loss." The stone appeared sound after 25 years of exposure and yet it showed a high loss in the sodium sulfate test. One might raise the objection that had this same stone been exposed to the sodium sulfate test originally, before its 25 years of exposure to the weather, the result might have been different because of the destructive effects of the exposure. However, tests have been made in another laboratory, first, on a sample of the stone from the trickling filter and, second, on a sample supplied by the producer and representing to his best knowledge the kind of material originally supplied to the filter. The percentages of loss of these two samples was practically the

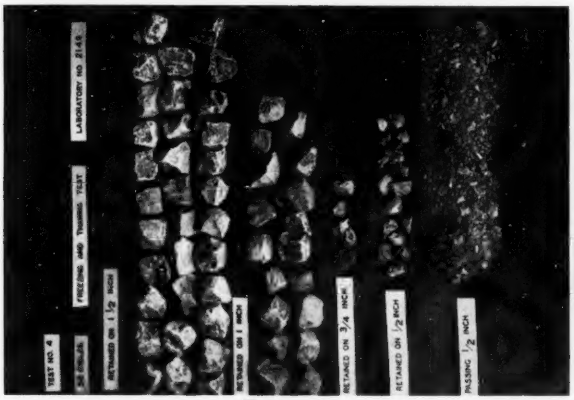


FIGURE 2.
Effect of 50 cycles of freezing and thawing on sample of 50 pieces, originally retained on 1½ in. sieve. After the test 10 per cent passed the ½ in. sieve.

same, thus indicating no ill effects due to exposure.

The indications from the above described case, although not entirely conclusive, are surely strongly indicative that the sodium sulfate soundness test has given false results, and a false idea of the value of this particular limestone for use in trickling filters. The limestone stood up in service, yet it fails in the sodium sulfate test.

It might be of interest to compare the results of 50 cycles of freezing and thawing on the trickling filter material with 20 cycles of the sodium sulfate test made on the same material. In Fig. 2 is shown a view of the sample after 50 cycles of freezing and thawing. It will be noted that there is considerably less breakdown after 50 cycles of the freezing and thawing test than occurred during 20 cycles of the sodium sulfate soundness test. For illustration, the amount of material lost after the freezing and thawing test, passing through the ½ in. sieve, was 10 per cent as compared with 49.9 per cent in the case of the sodium sulfate test.

Reference should be made to the article by Curtiss Cantrill and Louis Campbell in the present issue of the Crushed Stone Journal in which the unreliability of the sodium sulfate test is again very strongly indicated. In the Kentucky investigations reported by Messrs. Cantrill and Campbell, it is definitely proven that the chert gravels from the Tennessee and Cumberland Rivers have given exceptionally poor results when used as the coarse aggregate in concrete roads and yet when the soundness of these materials was investigated by the sodium sulfate soundness test they appeared to be sound. As a matter of fact, the chert is far from sound as evidenced by its behavior in service. On the other hand, the limestone on an average showed a percentage of loss of 12.1 and this would be accounted unsound by most specification writers; yet in service the limestone concrete roads are giving a most excellent account of themselves. Here, then, are instances, perhaps a great many of them, in which the sodium sulfate test might accept very dangerous materials whereas it might reject a material such as limestone which has given superior service results.

Certainly a test such as this should not be used blindly for the purpose of either rejecting or accepting materials. It would seem that enough lack of parallelism between test results and service behavior is on record to warrant a move toward discarding the sodium sulfate soundness test altogether.

Expenditures on State Highways and Highway User Contributions to State Treasuries During 1938

EXPENDITURES for State administered highways in 1938 amounted to $895,132,000, according to reports of State highway departments to the Public Roads Administration. This is $23,654,000 less than was expended in the preceding year.

The States spent $523,738,000 for construction of highways and $232,388,000 for maintenance. These expenditures were divided $638,685,000 on primary State highways, $74,970,000 on secondary roads in 13 States, and $42,471,000 on urban extensions of State highways. The outlay for administration, equipment, highway police and interest on debt amounted to $139,006,000. In addition $84,711,000 was used for retirement of debt, $121,262,000 was transferred for use on local roads and streets, $7,898,000 was used for highways not on the State system, and $26,119,000 was used for non-highway purposes. The total expenditure for all purposes was $1,135,122,000.

The total income to State highway departments was $1,096,908,000, and balances on hand brought the total funds available to a billion and a half dollars The current income from State sources was $817,343,000 of which motor vehicle users supplied over 98 per cent. Taxes on property no longer supply significant amounts to State highways funds. The net amount of funds received from Federal sources was $196,826,000. Income from sale of bonds, transfers from local units and from miscellaneous sources brought the total income from other than current State revenue sources to $279,565,000.

Highway users made direct contributions to State treasuries of $1,177,010,000 in the year 1938, according to data collected from State agencies by the Public Roads Administration. State gasoline taxes provided $771,764,000, motor vehicle fees $388,825,000, and motor carrier taxes brought in $16,421,000.

The net funds distributed amounted to $1,175,202,000. Over 44 million dollars was assigned to collection costs, $691,063,000 went for State highway purposes, $273,865,000 went for local roads and streets, $7,906,000 was assigned to park and forest roads, and $158,284,000 was assigned to non-highway purposes such as relief, education, and general funds.

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